PRIVATE AND CONFIDENTIAL

RESEARCH DEPARTMENT

VISIT TO U.S.A., AUGUST 7th - 28th 1960

Report No. A-060

(1960/26)

THE BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION

RESEARCH DEPARTMENT

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1. INTRODUCTION

Recent developments in certain U.S.A. electronics laboratories and broadcasting organisations are of considerable interest in relation to the present and possible future work programmes of Research Department.

These developments may be classified under three main headings:

(i) television standards conversion
(ii) video-magnetic and thermoplastic recording
(iii) storage and camera tubes

This report outlines the information and impressions concerning these topics gained during a three-week tour, which included visits to a number of U.S.A. organisations whose interest in such subjects was either known or considered highly likely. The report also includes information obtained concerning matters which, although unrelated to the subjects listed above, are known to be of interest within the Engineering Division.

The itinerary was arranged in co-operation with the Engineer-in-Charge at the New York office whose influence ensured that, during each visit, the writer made contact with the relevant experts rather than with sales-promotion staff.

The tour included visits to:

Telechrome Inc., Long Island, N.Y.
Raytheon Manufacturing Co., Waltham, Mass.
R.C.A., Camden, N.J.
R.C.A., Lancaster, Penn.
C.B.S., New York City, N.Y.
N.B.C., New York City, N.Y.
A.B.C., New York City, N.Y.
General Electric Research Laboratories, The Knoll, Schenectady, N.Y.
Ampex Corporation, Redwood City, California
Station KMJ-TV, Fresno, California
Hughes Research Laboratories, Malibu, California
Station KTLA, Los Angeles, California
C.B.S. Television City, Hollywood, California
Western Electronic Show and Convention (WESCON), Los Angeles, California.

2. STANDARDS CONVERSION

Work in this field is almost exclusively confined to the three major networks. So far, a substantial share of their experimental effort has been concerned with the problem of "repeating" conversion, although a considerable interest is growing in the problems associated with conversion between standards having 50 c/s and 60 c/s field frequencies. As in Britain, repeating conversion is of interest in the U.S.A. in that it can provide means whereby signals from remote sources may be made synchronous with local signals, and rapid switching, fading or superimpositions may be carried out without disturbance to the viewer. Opinions expressed by network engineers suggested that the successful development of a converter operating between 50 c/s and 60 c/s standards would be of considerable value in allowing a further expansion in the sales of programmes abroad.

2.1. Developments at N.B.C.

The standards conversion equipment is located in New York and at present consists of a 14-inch picture monitor (made by M.W.T.), containing the normal form of cathode-ray tube (having a white-fluorescing phosphor), together with an R.C.A. camera, employing a 1-inch Vidicon tube, of the type used for film transmission in the U.S.A. This basic arrangement was demonstrated as a repeating converter and, although horizontal definition was reasonably well conserved (presumably by suitable equalization), poor vertical resolution and flare effects in both the cathode-ray tube and the camera tube led to an output picture of rather inferior quality. However, this performance was shown to be radically improved by the addition of a vertical-aperture equaliser[1] developed by the R.C.A. Research Laboratories at Princeton, New Jersey.

The principle of this aperture equaliser may be understood by reference to Fig. 1. The input video signal is applied to two delay devices in cascade, each delay corresponding to the duration of one television line; the delay devices consist of

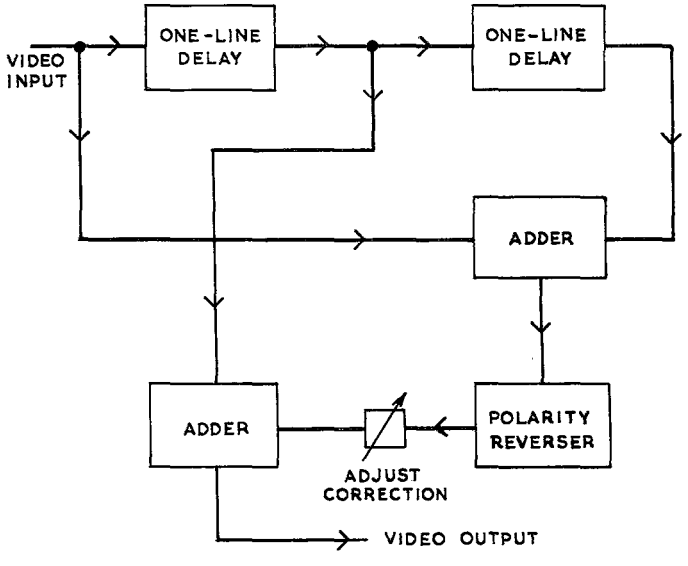

Fig. 1 - R.C.A. vertical aperture equaliser

quartz blocks through which acoustic waves, amplitude modulated by the television signals, are propagated. The acoustic carrier has a frequency of 30 Mc/s. The principal component of the output signal is extracted from the junction between the two delay devices, and to this component are added contributions both from the input point and from the output of the second delay device; these latter contributions, however, have suffered polarity reversal before addition to the main signal. This arrangement produces a scanning aperture which compensates for the dilution of information in one television line by information from adjacent lines of the same *field*. The dilution of information between adjacent lines of a television *picture* cannot be dealt with by this arrangement (the problem would involve a delay of at least one television field) but, nevertheless, the equaliser is sufficiently effective, when used with the N.B.C. standards converter, to cause a marked improvement in the output picture. The fact that the equaliser incorporates quartz blocks, whose delay (at constant temperature) is fixed, would infer that the equipment could only be used with crystal-controlled television signals. However, the use of short, adjustable, "trimming" delays has permitted the equaliser to operate satisfactorily with "mains-held" signals, the mains frequency remaining sensibly constant throughout the period of interest. Further development could lead to the use of servo-controlled delay devices giving a "one-line" delay over a wide range of line frequency.

N.B.C. are planning to study the conversion between standards having 60-fields-per-second and 50-fields-per-second field frequencies and are borrowing from M.W.T. a "flicker-correcting" unit which will be arranged to modulate the signal applied to the display cathode-ray tube. In addition, of course, it will be necessary to change the type of cathode-ray tube employed in the display to one having a substantially longer afterglow.

2.2. The C.B.S. Installation

Work on standards conversion at C.B.S. in New York is proceeding along lines very similar to those adopted by the B.B.C. An experimental converter was inspected and discussed, but unfortunately no demonstration was available. The equipment employs a display based upon a 7-inch cathode-ray tube having a willemite phosphor; the gun and bulb designs are identical with those used for a flying-spot scanner. The camera is again of the type used for film scanning and employs the R.C.A. 1-inch Vidicon. Pre-display signal processing, time bases, e.h.t., etc., are furnished by G.P.L. equipment previously used for kinescope recording and C.B.S. have provided a small experimental unit adding a reference pulse once per input television line. Flicker correction is carried out by a prototype unit purchased from Fernseh G.m.b.H; this is said to consist of one keyed-a.g.c. loop. Although C.B.S. could not demonstrate this apparatus, they showed a great interest in the results the B.B.C. has obtained, and expressed very favourable comments when a short recorded extract, converted from a 405-line, 50 fields/sec programme, was replayed on one of their videotape machines. C.B.S. are, at present, consolidating their developments and have purchased, from Fernseh G.m.b.H., a converter based upon the principles already investigated. After some modification by C.B.S., the equipment was used operationally during the recent Olympic Games.[2]

2.3. Standards Conversion at A.B.C.

A.B.C. have been carrying out some investigations into "repeating" conversion, but, at present, this work has had to be interrupted. They have performed

experiments using a display tube of a type used for kinescope recording (employing a P.11, blue-emitting phosphor) in conjunction with, once more, a 1-inch-Vidicon camera and its associated channel. The results of these experiments have led them to explore the possibilities of acquiring a C.P.S. Emitron camera equipment, as used by the B.B.C. They are of the opinion that a considerable amount of further work will be necessary before they have an installation suitable for regular operational use.

2.4. Developments in Industrial Laboratories

Discussion in a number of U.S. electronic laboratories elicited the fact that no work is, at present, being undertaken there to develop a standards converter as a commercial product. However, it was quite firmly stated at R.C.A., Camden that interest in this field was increasing very appreciably. It was also stated that the R.C.A. Research Laboratories at Princeton have looked into the problem, and, as a result of theoretical study, have proposed a scheme for converting between standards having identical field frequencies, which relies upon the use of magnetic tape scanned by two differing rotating-head assemblies. It was suggested that by recording and replaying at differing head-to-tape velocities, it would be possible to change the duration of any one television line. In order to ensure that the converter output provided a smooth flow of regular synchronizing pulses and picture information, it would be necessary to omit, repeat and temporarily store input information. These problems, it was suggested, could be solved by suitable gating and delay means; the delay device proposed consisted of the quartz block, through which supersonic acoustic waves carrying the video information would be propagated, as used in the vertical aperture equaliser.[1] The scheme has not aroused a great deal of interest and, as far as can be ascertained, no experimental work has yet been done.

3. VIDEO-MAGNETIC AND THERMOPLASTIC RECORDING

3.1. Video-Magnetic Recording

As is well known, the organisations principally active in this field are the Ampex Corporation and the Radio Corporation of America. At present R.C.A. are principally concerned with the further development and improvement of their standard recorder whilst Ampex, having now reached a position where they have more than one type of recorder in production, are concentrating on the development of equipment which can extend the use of and improve the picture quality obtained from recorders already in operation. On the assumption that the Ampex and R.C.A. recorders produce what one may term a "standard" recording, it is of interest to note that Telechrome Inc., in collaboration with Epsylon of Great Britain, are considering the marketing of a "non-standard" recorder developed by the Victor Company of Japan. It is claimed that this equipment will cost approximately half the price of a "standard" recording machine.

3.1.1. Developments at the Ampex Corporation

The present developments of particular interest are Inter-sync and Amptec.

3.1.1.1. Inter-sync

Information[3] concerning Inter-sync has been fairly widely disseminated in this country. Basically, it consists of the modification and extension of the head-

drum servo arrangements so as to permit the output from the machine to be in approximate synchronism with a train of synchronising pulses fed to the machine, say, from the local studio generator and may be used in both the recording and replay modes. In addition to the normal control signal (240~ in the U.S.A. 250~ in Europe) reference is made to the picture and line-frequency components in the output from the replay circuits; in the record-mode these circuits provide a monitoring signal obtained from a low-level sample of the recording-head current. In essence, the modifiedservo arrangements consist of two loops. In the first, synchronising signals from the recorder are compared with the master sychronising pulses and the phase of the head-drum driving signal is adjusted, by a motor-driven phase shifter, so as to achieve approximate time coincidence between corresponding odd (and even) fields. This adjustment thus ensures that the recorder output is synchronised at picture frequency. The second loop now becomes operative and a comparison is made between the phase of the line-frequency pulses from the recorder and those in the master pulse train. An error signal is developed which is used to operate an all-electronic, fast-acting phase modulator in the head-drum drive circuit. It is claimed that a fairly high degree of synchronism can be achieved between the recorder output and the master pulse train. However, it should be noted that the broadcast networks and Ampex themselves do not consider that the use of Inter-sync, at this stage, gives a degree of synchronism which would allow long periods of transmission where both the recorder output and signals from another source are present simultaneously. It has been said, however, that Inter-sync arrangements can give adequate performance during a short transition period or "hand over".

3.1.1.2 Amptec

This device, now under laboratory development at Ampex Corporation, is based upon an idea developed by C.B.S. in Chicago where it was known as Autotec. Ampex have recently acquired both the idea and the man responsible for its development. Operational experience with magnetic recorders has led to the conclusion that it is very difficult to avoid some small degree of time modulation in the output signals. Such time modulation may be due to many causes but, in general, is principally the result of head-quadrature errors or misalignment between the replaying-head drum and the tracks recorded on the tape. The result of this time modulation is quite often visible to the viewer as irregularities in the reproduction of picture verticals; these effects are sometimes termed "cogging" and "scalloping".

The basic philosophy underlying Amptec is as follows. The time modulation causing the above-mentioned unwanted effects may be removed if the output of the recorder is passed through a delay line whose delay may be varied rapidly in a suitable manner. In discussion, the Ampex engineers were somewhat hesitant to reveal the significant details of Amptec but sufficient information was gleaned to convince the writer that the arrangement is, broadly, as shown in Fig. 2. The synchronising signals in the recorder output are used to lock a line-frequency oscillator by means of the customary phase-comparator and reactance-stage combination. The loop includes a filter having a fairly long control time-constant. The frequency of the oscillator can thus be made equal to the average frequency of the line-synchronising pulses in the recorder output. In the phase-comparator the line pulses from the recorder are directly compared with the output from the controlled oscillator and thus the error signal developed represents, on a line-by-line basis, the time-displacement error. The error signal, after suitable smoothing, is then used to control the

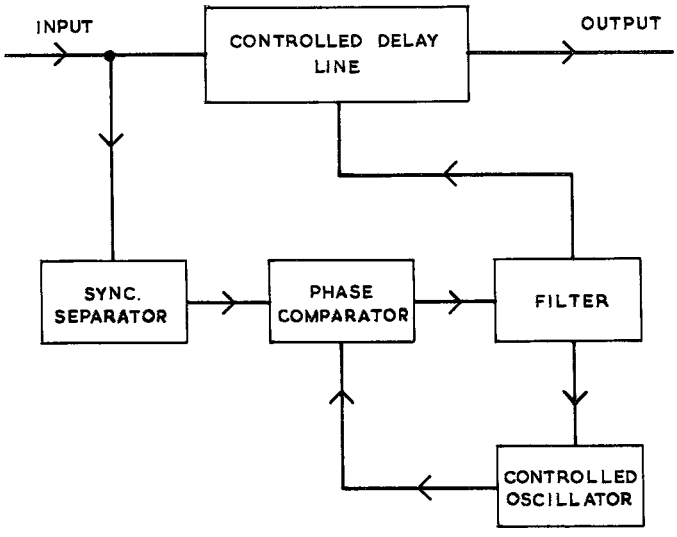

Fig. 2 - Functional diagram of Amptec

delay of a special delay line through which the complete recorder output signal is passed. The controllable delay line is formed by fixed series-inductance elements together with variable shunt-capacitance elements; the variable capacitances consist of semi-conductor junction diodes biased in the non-conducting condition. Variation in the bias influences the effective thickness of the semi-conductor barrier and thus affects the junction capacitance.

A demonstration of Amptec in its experimental form was seen in which a videotape recorder was maladjusted so as to produce serious "cogging" errors. The time displacement between the signals from successive heads was measured to be about $1\mu s$. When viewed on a picture monitor having a long time-constant line-frequency oscillator, this appeared as a gross distortion. After processing by Amptec the viewed picture was seen to be radically improved. The time-displacement error during that line immediately following head switching was reduced (in the middle of the picture) from $1\mu s$ to approximately $\frac{1}{3}\mu s$. The error then fell rapidly to an imperceptible amount until switching between heads occurred again. The demonstration was sufficiently convincing to prompt the thought that there may be some danger, if Amptec is widely adopted, of videotape machine operators not paying sufficient attention to head-drum adjustment, particularly during replay. Unfortunately, a demonstration could not be given using a picture monitor with a hard-lock or driven line time base. However, the output from the Amptec equipment, when viewed on a monitor having a very short time-constant, appeared free from noise "ragging" effects. The performance of the experimental Amptec unit is such as to suggest that it could well provide the solution to the difficulties now being experienced, in this country, with those domestic television receivers having flywheel-type line-deflection oscillators whose properties[4] result in a visible disturbance to the viewed picture from a recorder.

The writer discussed with the Ampex engineers the relative merits of Amptec and an analogous proposal made by Research Department some time ago.[5] The Ampex engineers agreed that the Research Department proposal was quite feasible and did

not appear to doubt that it could be made to work satisfactorily. They commented, however, that it would probably result in a more complicated design and bulkier equipment. It must be remembered, however, that the B.B.C. proposal is not only intended to correct the time modulation of the recorder output (as in Amptec) but, if required, may be used to provide an output synchronous with an external signal (as in Inter-sync). Ampex are now engineering Amptec using transistors and hope to have a marketable version in production by the Spring of 1961. Provided (a) the commercial product performs as well as the experimental arrangement seen by the writer and (b) no unforeseen difficulties are encountered when Amptec is used with Inter-sync (this problem is to be thoroughly investigated by Ampex shortly), it would appear uneconomic for the B.B.C. to develop its own version of such equipment.

3.1.2. The Victor (Japanese) Recorder

Discussion with Mr. Popkin-Clurman of Telechrome Inc. revealed that current Japanese work in the field of magnetic recording includes the development, by the Victor Company, of a two-head machine which, whilst showing some similarity to the Toshiba[6] single-head recorder, avoids the rather severe mechanical problems associated with a full turn of tape around the rotating-head drum.

The essential features of the Victor recorder are illustrated in Fig. 3. Fig. 3(a) shows the layout of the tape traction and illustrates the positions of the recording heads together with the associated capstan, tape reels and guides. The slant position of the tape lapping the head drum is shown in Fig. 3(b). The two heads lie at the extremities of a drum diameter and the drum is rotated so as to complete one half revolution per television field. Each head thus records one input field per half revolution and the slant angle (4°), at which the tape passes over the drum surface, results in a recorded track (corresponding to one field) which is 27 in. long. Fig. 3(c) illustrates the pattern of tracks recorded on the tape. Track AB is recorded by one head and, say, represents an even field; track CD is recorded by the other head and, under these circumstances, represents an odd field. Switching between heads takes place during replay only and is carried out during the field-blanking interval. By arranging that the tape is in contact with the drum for more than the 180° required by the positions of the heads, information at the beginning and end of each field is recorded twice (at the extremities of adjacent tracks): this simplifies the switching between heads and is similar to the arrangement adopted in the Ampex and R.C.A. recorders. The relative velocity between either video head and the tape is approximately 1600 in. per sec and, with a tape speed of 15 in. per sec, the tracks are laid down at quarter-inch intervals. The recording and replay video channels together with the head-drum control servo system are still under development. However, using a F.M. system in the video recording and replay channels and a 30 c/s drum-servo reference signal, the equipment is reported to show some promise. The peak video signal-to-r.m.s. noise ratio is said to be in the region of 34 dB.

As mentioned earlier in this report, Telechrome and Epsylon are contemplating the exploitation of this recorder. They anticipate that the recorder may find its main application in industrial television systems but hope that it may also be considered by broadcast networks for such internal applications as time-zone delay. It is considered unlikely that this machine will compete seriously with the Ampex and R.C.A. machines for general broadcast use, particularly in view of the very difficult editing problem posed by the video-track arrangement of Fig. 3(c).

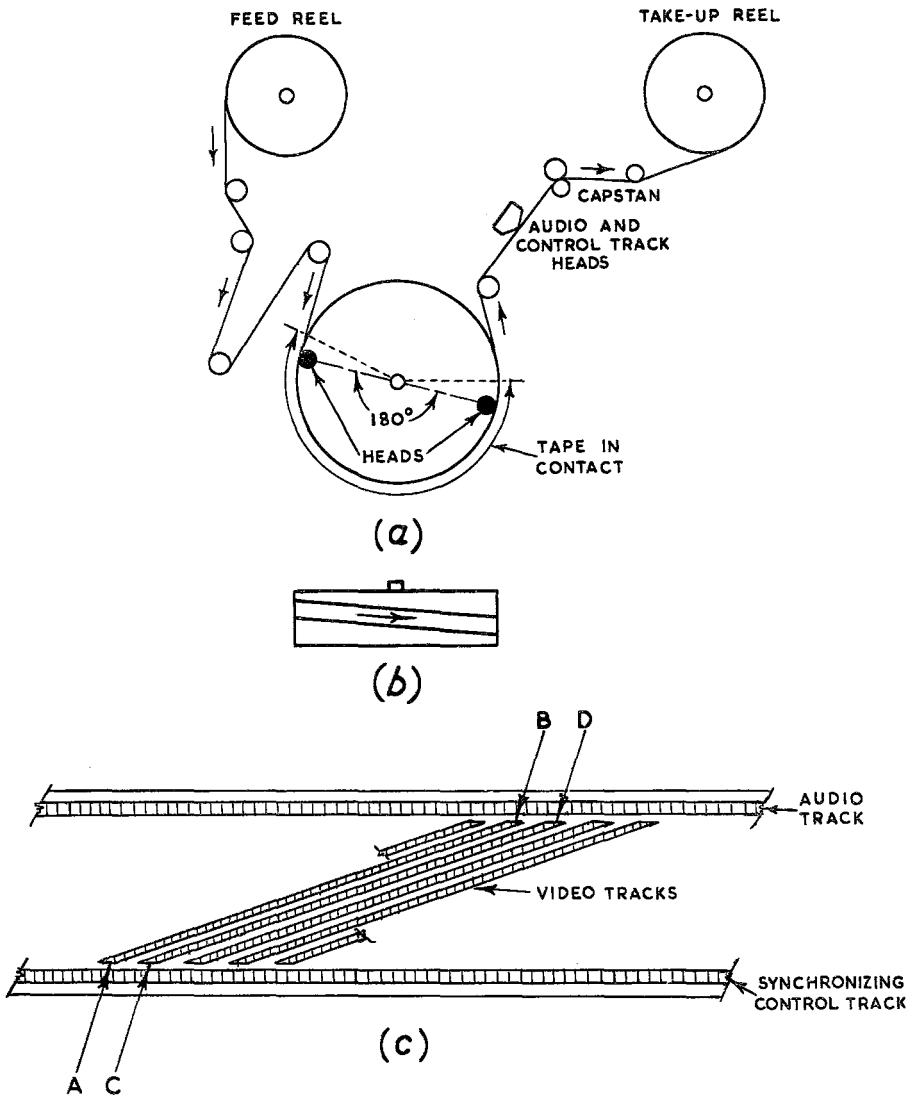

Fig. 3 - Victor (Japanese) recorder

3.2. Thermoplastic Recording

Thermoplastic recording was discussed and a demonstration seen at the Knoll Research Laboratories of General Electric. The system has been described and fairly widely publicised in an article by Dr. W.E. Glenn,[7] who was present at the time of the writer's visit. In brief, the system consists of recording on a thermoplastic film base a series of indentations representing the shades of grey in the television picture. These indentations are produced by first scanning the tape with a stream of electrons, of 7-8 kV energy, which produce a series of electric charges below the surface of the tape. The tape is then heated to the flow condition, and the electrostatic forces now produce a mechanical distortion of the tape as a function of their intensity. On cooling, these mechanical distortions are preserved in a permanent form. The electron gun, which is used to bombard the tape, incorporates a deflector electrode to which a high-frequency carrier is fed; this, in turn, is modulated by

the television signal. At present a carrier frequency of 41 Mc/s is employed and the television signal is applied as negative modulation so as to produce a varying form of spot wobble where the maximum degree of wobble corresponds to black and the minimum to peak white. Electron bombardment of the tape takes place in vacuo but, at the present stage of development, the heating of the tape to produce the mechanical distortion is performed externally in air. The recording chamber may be pumped out at a speed such that recording may be carried out about one minute after the tape has been inserted and the door closed. Some difficulties have been experienced due to variations in the mechanical and electrical properties of the tape, which is supplied by another division of the General Electric Research Laboratories. The tape used is transparent, 16 mm in width and is doubly perforated compared with ordinary 16 mm ciné film. The recording actually occupies some 5 mm of the width available. In the recorder the tape is moved continuously at some 10 inches per second to provide the vertical component of scanning; 60 fields of the television signal are thus recorded as separate images in this interval. Reproduction of the recorded film is at present confined to optical projection. In the projector a series of line light sources are imaged on to the recording and a Schlieren optical system is interposed between the recording and the main projection lens; this Schlieren system contains a series of opaque bars corresponding to the line light sources. In the absence of refraction by the recording no light can pass to the screen. The mechanical indentations corresponding to the recorded signal produce a controlled refraction of the light resulting in an optical image of the recording.

A demonstration was seen in which a short recording was projected. The projected image was somewhat unsteady and rather marred by a rain of white spots, but the resolution and grey scale appeared quite satisfactory. The writer was assured that the unsteadiness was due to mechanical imperfections in the replay projector; the white dots were said to be due to dust particles adhering to the surface of the recording. A development team is now engaged upon the problem of a reproducer whose performance would be adequate to match the potentialities of the recording. It is proposed to use "pinch roller" rather than "claw" traction in the reproducer and work is already proceeding upon the dual lines of (1) optical projection into a Vidicon camera tube and (2) the use of continuous-motion flying-spot scanning techniques. General Electric maintain that the white spots marring the picture can be eliminated by preventing the access of dust to the film during recording and reproduction; this will be taken care of in the later work. It is fairly obvious that the recorder and its associated reproducer are still at a very early stage of development. Success could obviously lead to a very powerful recording technique combining the speed and immediate-replay facilities of magnetic recording with the simple editing techniques of film.

4. STORAGE AND CAMERA TUBES

4.1. Storage Tubes

In view of possible further developments in standards conversion and slow-scan television systems, a series of visits was made to various U.S. organisations known to be active in the field of storage tubes. The tubes seen and discussed fall into two main classes. The first, which may be termed the electronic "read-out" type, accepts an electrical input and delivers an electrical output signal. The second

class of tube accepts an electrical input, but produces, as output, some form of optical image; such tubes are known as direct-view storage tubes.

4.1.1. Electronic "Read-out" Tubes

Of the organizations visited, those mainly concerned with electronic "read-out" tubes are Raytheon and R.C.A. (Lancaster). The tubes have been designed mainly for application in the radar field where it is advantageous to convert the normal "P.P.I." display into a high-definition 945-line/60-field television picture which may, in turn, be viewed simultaneously on many monitors without severe restriction of the ambient lighting. Both single-gun and double-gun tubes have been developed.

4.1.1.1. Single-gun Tubes

Most of the single-gun tubes available have been developed from that proposed by Hergenrother and Gardner[8] and require a four-mode sequence in their operating cycle; these modes are usually termed "prime", "write", "read" and "erase". The storage surface employed consists of a fine metal mesh (1000 meshes to the inch) coated on one side by an insulating-dielectric layer. This mesh is scanned by electrons from a suitable gun positioned on the same side of the mesh as the dielectric coating. A decelerating electrode is interposed between the electron gun and the mesh and a collecting electrode is located on that side of the storage mesh remote from the gun. The operation of such a tube may be described as follows:

(a) "Prime"

In this condition the potential of the mesh is adjusted so that electrons arrive at the insulated surface of the mesh with low velocity. This causes the insulator to be charged negatively toward gun-cathode potential.

(b) "Write"

The mesh potential is now adjusted to be relatively high with respect to the gun cathode, and the scanning-beam current is modulated by the signal to be stored. The energy of the electrons is now sufficient to exceed "first crossover" and, owing to the secondary-emission coefficient exceeding unity, a layer of positive charges is laid down on the mesh coating. The intensity of these charges is related to the input signal.

(c) "Read"

During the "read" process the mesh potential is lowered to a value somewhat below that of the gun cathode so that electrons arriving at the plane of the mesh are subjected to a retarding field whose intensity is reduced by the stored charges deposited upon the insulated surface of the mesh. That proportion of the beam current which penetrates the mesh and arrives at the collector electrode thus depends upon the stored charges. Under suitable operating conditions the reading electrons may be prevented from landing on the mesh. Signals may thus be derived for a large number of "reading" scans.

(d) "Erase"

Finally, erasure is carried out by applying to the storage mesh a potential similar to that used during the writing cycle whilst simultaneously scanning the mesh with a relatively high constant beam current.

The latest version of such a single-gun tube (type QK 685) was demonstrated by Raytheon. The tube appeared to have a fairly clean background, good resolution (greater than 600 elements per target diameter) and produced sufficient output signal to give a peak video signal-to-r.m.s. noise ratio in excess of 34 dB (with a triangular spectrum). The input/output characteristic appeared somewhat non-linear but could probably be improved by suitable correcting circuits in the signal path. The application of this tube is, of course, mainly determined by the requirements of the four-mode cycle, particularly when it is borne in mind that the priming action may take one or two seconds. This would restrict its use, by a broadcaster, to the fields of slow-scan television systems and "picture freeze".

A single-gun tube potentially suitable for television standards-conversion applications was discussed (but unfortunately not demonstrated) at R.C.A., Lancaster. This tube, the Radechon,[9] is well known and has a mode of operation permitting comparatively rapid writing, reading and erasure. The R.C.A. version (type 6499) is said to operate quite satisfactorily, as a short term store, with writing and reading scan velocities of the order of 40 μs per target diameter. The resolution of the tube, in terms of a television picture or field, is rather poor but would probably be adequate if most of the target surface were used to store one television line. The tube may, therefore, merit consideration as a "line" store.

4.1.1.2. Dual-gun Tubes

Dual-gun tubes have been developed in order to avoid some of the restrictions imposed upon the use of the single-gun version by the requirements of the operating cycle. Their operation is based upon an extension of the principles employed in the single-gun tube (such as the QK 685) in that the collecting electrode has been replaced by a reading-gun section scanning that side of the storage mesh remote from the writing gun. The reading gun operates at a potential such as to produce low velocity electrons which penetrate the storage mesh to an extent dependent upon the stored charges. Those electrons which penetrate the storage mesh are collected by the decelerating electrode located between the storage mesh and the writing gun. The tube is very similar to the VCRX 350.[10] Under certain tube operating conditions it is possible to write and read simultaneously, a form of self-priming and erasure taking place by permitting some of the reading-beam electrons to land on the insulated surface of the storage mesh. Unwanted breakthrough of the writing signal into the output circuits is difficult to avoid unless the reading beam is modulated by a radio-frequency carrier (at 30-60 Mc/s); the output then appears at the decelerating electrode as a corresponding r.f. signal amplitude modulated by the required video information.

Raytheon demonstrated their dual-gun storage tube type CK 7702. In the demonstration a 525-line/60 fields-per-second television signal was applied to the writing section and the reading section was operated according to the same standards; the reading-section scanning circuits were, however, locked to an independent source of synchronising pulses. After an initial priming operation, in which all the reading beam electrons were made to land upon the insulated storage mesh, the tube appeared to operate stably for a considerable time. Even under the best conditions the self-prime and erasure could not reduce the effective storage time below about one second. The output picture therefore had very considerable after-image smear. Background irregularities were, again, not serious but resolution and signal-to-noise ratio

appeared a little inferior to that seen from the single-gun QK 685. The grey scale was, again, such as to require correction. Once more it would appear that, in a television broadcasting organisation, tubes such as the CK 7702 are likely to find application in the fields of slow-scan systems and "picture freeze" only.

4.1.2. Direct-view Storage Tubes

Examples of direct-view storage tubes were seen and discussed at R.C.A. (Lancaster) and the Hughes Research Laboratories. All the tubes were based upon the same principles[11] as those employed in the E.E.V. tube type E702. Tubes are available in a wide range of sizes (5 in. to 21 in.) but all appear to suffer from similar limitations in performance. With perhaps one exception (R.C.A. type C73959) the tubes showed pictures of somewhat poor resolution when used to display television images. "Background" was also poor in having a "linen weave" appearance (due to the shadows of various meshes incorporated in the tube structure) and the tubes suffered from rather patchy and uneven sensitivity variations over the screen area. The reproduction of the grey scale was markedly non-linear but this could probably be partially compensated by suitable external circuit arrangements. The tube characteristics permitted erasure to be effected either as a continuous process or during a discrete and separate interval in the operating sequence; the minimum time required amounted to a substantial fraction of a second.

Although a greater range of sizes is available there it would appear that, at the present time, the direct-view storage tubes produced in the U.S.A. show no really significant improvements in performance over similar tubes available in Britain.

4.1.2.1. A "Picture Freeze" Application of Direct-view Storage Tubes

An aid to the editing of video-tape recordings has been developed at KTLA, Los Angeles (an independent broadcasting station owned by Paramount Inc.). This device, referred to as "Picture Freeze" or "Tapeiola", is used in conjunction with an Ampex videotape machine and consists, in essence, of four 5 in. direct-view storage tubes (made by Hughes) displaying single television pictures separated, in time, by certain adjustable intervals. Counting and gating circuits are provided which, together with the editing channel of the recorder, permit the tubes to display the pictures recorded on the tape in the region of a required editing point.

In a demonstration to the writer, the operator elected to locate a "camera-cut" between two scenes in a recorded programme. The location of this "cut" was known with sufficient accuracy to allow the "Picture Freeze" device to be operated approximately two seconds before the expected "cut" appeared. The four storage tubes now displayed single pictures derived, at one-second intervals, from the replayed recordings; as each tube was energised, cue pulses were recorded on the tape. As the four-second period included the required cut, the editing point was thus located within one second. The counters and gates were now "programmed" with this information, the time interval between displays was adjusted to one-third of a second and the required portion of the recording was replayed. The relevant "one-second" cue pulse now automatically initiated the display cycle, further cue pulses (at one-third-second intervals) were recorded and the "cut" located within one-third of a second. This procedure was repeated with further shortening of the intervals between displays (and

cue pulses) from one-third of a second to one-tenth of a second and from one-tenth of a second to one-thirtieth of a second until the actual picture period including the cut was located. The tape was then suitably marked for cutting and splicing.

The equipment was mounted in a small console and was of a complexity approximately equivalent to four waveform monitors together with a synchronising-pulse generator. The pictures displayed by the storage tubes were rather poor but, nevertheless, adequate for the purpose.

4.2. Camera Tubes

Some interesting camera-tube development work is being carried out, at the present time, by General Electric; during a visit to their Research Laboratories the opportunity was taken to discuss this. They have developed a 3 in. image orthicon (type GL-7269) which incorporates a magnesium-oxide target some 500 A° in thickness. Owing to its high secondary-emission coefficient of approximately 13, this target material offers an increase in camera-tube sensitivity of more than 3 to 1 over the normal form of glass target which has a secondary-emission coefficient lying between 3 and 4. The extremely thin nature of the new target is an essential feature in that the required properties of electrical conductivity can only be achieved this way; charge is conducted through such a film by electron carriers. With the thin target, loss of resolution and the limitation of storage time due to surface leakage of charge are substantially reduced. However, the extremely fragile nature of the film has necessitated the use of a wide (0·01 in.) spacing between the target film and the target mesh. Attempts to reduce this spacing have resulted in fracture of the target film due to electrostatic forces between the target and the mesh. As one might expect, the input/output characteristic of this tube shows a very long "knee" and the best signal-to-noise ratio obtainable is marginal in terms of broadcast television. Due to the high sensitivity, however, the tube can prove useful when pictures are required under conditions of extremely low incident light. Edge effects are somewhat less pronounced than one might expect with such a wide target/mesh spacing. This is probably due to the fact that the majority of the secondary electrons produced at the target surface by the primaries from the photo-cathode have very low emission velocities; they tend to fall back upon the target at the point of their emission rather than spread to neighbouring target areas. Comprehensive resolution measurements have not yet been carried out, but it is said that the target and gun have basic resolutions greater than 1000 lines per picture height. It has been found that the principal limitation of resolution is caused by scanning fields breaking through to the image section and thus causing movement of the electron image on the photo-cathode side of the target. Due to the fact that charge equalisation between the two sides of the target takes place by electronic rather than ionic charge carriers, it is stated that image "burn in" is effectively unknown with this tube; in fact a guarantee against this happening is given for the first 1,000 hours of operation. However, it has been noticed that the sensitivity very gradually decreases with time; this is said to be due to some effect at the target but is as yet not understood. One tube has been used for 10,000 hours and has lost two stops in sensitivity. The development of a 4½ in. version is unlikely, at least in the near future; it would be essential to support the target on some form of insulated mesh. The technique of supporting the magnesium-oxide film on an insulated mesh has been investigated[12] but this particular work has involved the use of too coarse a mesh for broadcast television purposes. Summarising, it can be said this special image orthicon is of

value only where it is essential to produce some form of picture under extremely poor light conditions. It has been tried in colour cameras, where its use has been mainly restricted to the televising of night baseball games played under artificial lights.

As is well known, R.C.A. have developed a 4½ in. image-orthicon camera channel (type TK12) as a competitor with the M.W.T. and E.M.I. channels available from this country. 4½ in. image-orthicon tubes are now in small-scale production and are said to be similar in characteristics to the P811 and the P822. R.C.A. (Lancaster) stated that once these tubes were in steady and reliable production they would probably proceed to further developments and improvements using some ideas they are now investigating.

5. OTHER TOPICS

5.1. Colour Television

Colour television in the U.S.A. is still progressing rather slowly. Only one of the networks is transmitting programmes regularly in colour; naturally this is N.B.C. The visit to R.C.A. (Camden) revealed that development work is proceeding which could lead to some improvement in the quality and uniformity of colour pictures. Work is in hand to modify some 150 three-tube colour cameras (of both the studio and film types) so as to improve their performance and stability; these cameras are those already supplied to broadcasters and the improvements will be fitted as modifications. Such items as scanning and amplifier units are being redeveloped to incorporate increased feedback. These units will have greater overload limits, will be less sensitive to temperature variations and will require less frequent adjustment.

A further improvement of three-tube camera performance has been achieved by replacing the dichroic-mirror assembly by a composite block incorporating the interference-type colour-selective surfaces. Such a block is illustrated in Fig. 4. As will be seen, this composite block consists of three sections whose surfaces are suitably coated to give the required colour-selection characteristics. The sections are ground before the material forming the interference filters is deposited and, after processing, the three sections are suitably bonded together. Trimming filters are attached to the outer surfaces of the composite block in the paths of the red, green and blue light beams. Due to the relatively large mass of glass involved and the necessity for avoiding mechanical strains, the processing and fabrication of the whole block takes about one week. It is claimed that this colour-selective beam-splitting block does reduce very substantially the unwanted optical effects that characterised the previous arrangement of separate plane mirrors. When asked whether any work was in progress on the use of 4½ in. image orthicons for colour-studio cameras, R.C.A. (Camden) were somewhat non-committal in their reply. However, conversation at the N.B.C. studios in New York did reveal that some work along these lines is now being actively pursued.

One of the reasons for the relatively slow progress of colour broadcasting in the United States is the very considerable use of magnetic recording. The sponsors and programme producers are now so accustomed, for monochrome programmes, to a technique of production where scenes are recorded out of sequence, the recordings

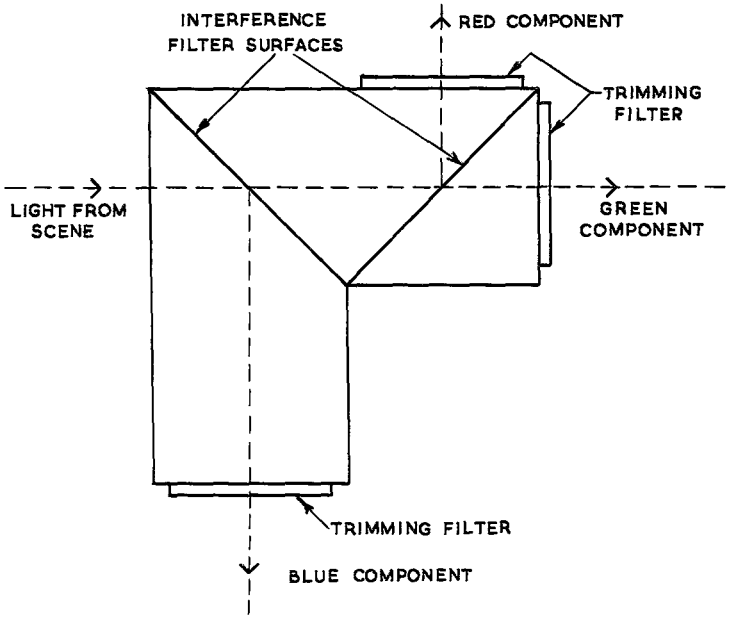

Fig. 4 - R.C.A. colour-selective block

being later arranged in order by editing, that they are rather loath to adopt different techniques for colour. Thus a very substantial proportion of the colour programmes broadcast by N.B.C. is in a recorded form. Further, the need for programme delay to accommodate the various time zones within the U.S. leads to a possible re-recording and hence additional degradation. Some colour magnetic recording was seen at N.B.C., New York, but it was difficult to assess the relevant characteristics of the process due to possible errors in the studio cameras. At the Ampex Corporation, however, the opportunity was taken to see the standard colour bar signal recorded and then replayed using one of the latest versions (type 1000C) of the Ampex recorder as adapted for colour use. Vectorscope measurements were made both before recording and after replay. The recording process appeared to introduce an appreciable amount of differential-phase distortion particularly for yellow and blue (some 10°). The dots on the vectorscope screen representing the colour vectors became diffused and noisy; this would indicate phase and amplitude fluctuations of the chrominance signal. When displayed on a colour monitor the colour bars appeared appreciably degraded by the presence of horizontal bands corresponding to the four heads; colour differences between individual head bands were readily observed. Very careful adjustment of the recording machine did not entirely eliminate these defects.

5.2. "Pay T.V." Proposals by Skiatron

During the visit to WESCON, information concerning a "Pay T.V." proposal was obtained from Dr. Axel Jensen, the engineering consultant concerned. This proposal has been made by Skiatron who, in co-operation with other industrial organisations, including I.B.M. and Motorola, hope to start commercial operation in San Francisco and Los Angeles about one year from now.

The essential features of the scheme may be described as follows:

Channel allocations by the F.C.C. are such that, in any one city area, it is usual to find one channel, within the band 54–88 Mc/s, free from local transmissions. The scheme proposed is outlined in Fig. 5 and employs a converter, fitted to the subscriber's normal receiver, which delivers output in the vacant channel: when requiring "Pay T.V." the subscriber will turn his station selector to this channel. The converter will be equipped with a further switch permitting the subscriber to select his choice of the "Pay T.V." television and sound programmes to be provided. Subscriber charging will be based upon an interrogating system by which the "state" of every subscriber's converter is indicated, to the central point, every few minutes.

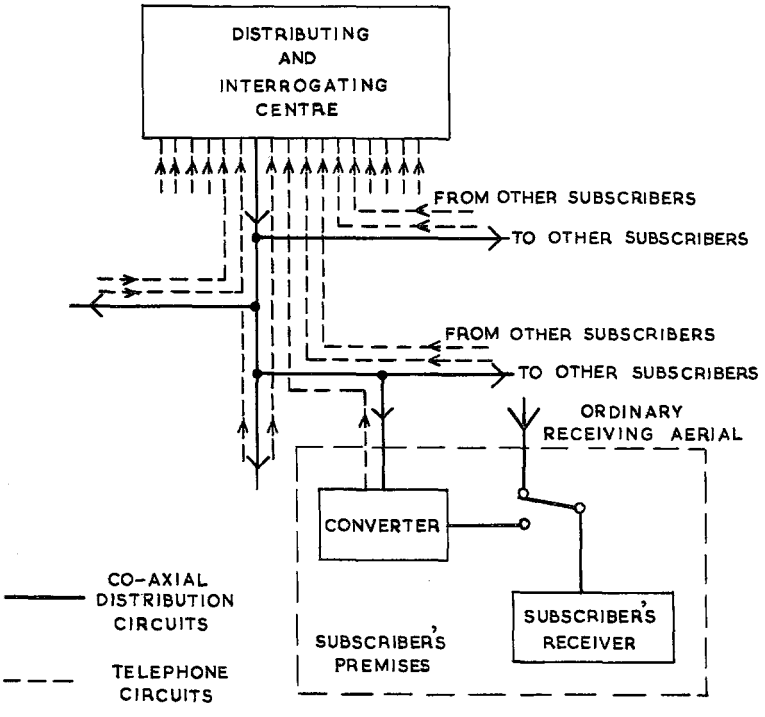

Fig. 5 - Skiatron "Pay T.V." scheme

Each converter will be fed from a co-axial cable network radiating from the central distribution point and will also be connected to this point by a separate telephone circuit. The signals carried by the cable network will cover a frequency range from 25–50 Mc/s and will consist of three television channels (with their associated sound channels), an interrogating channel and two further sound channels; one of these sound channels will be provided by frequency modulating the carrier of the interrogating channel.

The interrogating signal will consist of a 34 Mc/s carrier amplitude-modulated by groups of four sine-wave "bursts", each "burst" having a duration of about one television line. As twenty different "burst" frequencies, lying within the range 500 to 1500 kc/s, will be used, a large number of different four "burst" groups will be

available.* Each converter will be allocated one particular "burst" group to which, if switched on, it will respond. The response will be transmitted to the central point via the telephone circuit and will consist of a burst of audio tone, the frequency of the tone indicating the subscriber's choice of "Pay T.V." programme. The system will interrogate all converters in one particular area (of some 3,000 subscribers) every five minutes. As visualised at the moment, the equipment at a typical central point will be designed to feed and interrogate 100 of such areas. The information obtained by interrogation will be recorded on magnetic tape and this, in turn, will be used to feed accounting and subscriber charging machines. Dr. Jensen added, at this point, that a subscriber will only be charged if he continues to watch a particular programme for more than five minutes.

The advantages claimed are:

(i) the system avoids the use of scramblers and coin boxes, and

(ii) the converter is fitted to the subscriber's own receiver and does not, in any way, interfere with its use for viewing the ordinary broadcast networks.

5.3 Stereophonic Broadcasting

The WESCON programme included a session devoted to "Stereo Multiplex Broadcasting". Brief papers were first read outlining several of the multiplex systems[13] proposed for v.h.f. use in the U.S.A. (Zenith, G.E, Crosby, Calbest and Halstead). The paper of principal interest was given by A. Prose Walker, of the National Association of Broadcasters, who described the field trials recently carried out using the KDKA (Pittsburgh) transmitter. The systems tested included those mentioned above together with that proposed by E.M.I. Full details concerning the tests were not given but it was stated that measurements were made on all systems at field strengths of 1 mV/m, 200 μV/m and 50 μV/m. At the conclusion of the paper a demonstration was given in which the test tape, provided by Bell Telephone Laboratories, was replayed both as an original recording and after transmission and reception using only one of the proposed systems; the identity of the system was very carefully concealed. The signals, after transmission and reception by this one system, appeared to differ from the original recording by the presence of what sounded like multipath distortion.

In the ensuing discussion Mr. Walker stated that, in his opinion, the E.M.I. system was tested in the U.S.A., alongside the other proposed systems, in the hope that some organisation there would do further work on it but he did not think that E.M.I. themselves thought that it would be seriously considered at this stage. He added, nevertheless, that a system along such lines should not be ruled out in the F.C.C. deliberations. Comments on the performance of the E.M.I. system will be included in a forthcoming N.S.R.C. report and it is hoped that the F.C.C. will reach a decision on stereophonic broadcasting by the end of this year.

*If the order of the "bursts" in a group is significant then the number available is 116,280; if the order is not significant, the number is 4,845.